Statistical Properties of Tomographic Images: Theoretical Analysis and Computational Issues

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ABSTRACT

Single-photon emission computed tomography (SPECT) is an imaging modality that yields information regarding the *function* of organs within a patient. In SPECT, a radio-isotope labeled to a chemical compound is administered to the patient, which is then metabolized by the cells of the target organ. Data, in the form of γ-ray emissions, are then collected by a scintillation detector from various angular positions around the patient. The goal is to obtain an image which represents the bio-distribution of the radio-pharmaceutical, which can then be used to diagnose the presence of tumors or identify lesions.

The data collection process can be modeled as a linear system of equations. One can then apply techniques from linear algebra and matrix theory to solve the inverse problem. However, the measurements are corrupted by noise arising from the nature of photon decay, and so any inversion method affect the noise structure in the reconstructed image. Since humans have exhibited a decreased ability to detect signals (tumors) in certain noise correlation patterns, understanding how reconstruction algorithms process data noise is essential.

In this talk, we will first illustrate how noise can inhibit performance in a simple detection task. Next, we will examine how one can compute the ensemble statistical properties for classes of inversion methods. These will include linear/non-linear and iterative/non-iterative methods. Finally, we will show results for a class of *block-iterative* methods frequently used in clinical practice today. The results from the theoretical formulations will be compared with Monte Carlo simulations in order to validate the derivations. With knowledge of the ensemble statistical parameters, one could then use them to evaluate objective measures of image quality.

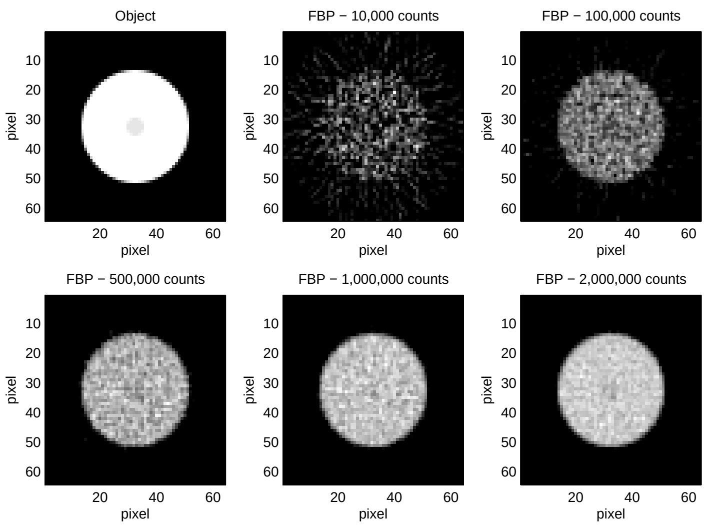

Figure 1. The effect of increased counts on the quality of the reconstructed image using the filtered back-projection method: Top row - disk object with 10% contrast disk signal (left); 10,000 total counts (middle); 100,000 total counts (right); Bottom row - 500,000 total counts (left); 1,000,000 total counts (middle); 2,000,000 total counts (right). As count level increases, the noise correlations become less of a factor in identifying the presence of the signal.